

What is Claimed is:

1. A magnetic recording medium for perpendicular recording, comprising:

a) a substrate;

b) an underlayer structure disposed over said substrate, said

5 underlayer structure comprising:

i) a first soft magnetic underlayer having a first thickness;

ii) a second soft magnetic underlayer disposed over said first soft underlayer and having a second thickness, wherein said first thickness is greater than said second thickness; and

10 iii) a non-magnetic spacer layer disposed between said first and second soft magnetic underlayers, wherein said first and second soft magnetic underlayers are anti-parallel coupled through said non-magnetic spacer layer;

c) an intermediate layer disposed over said underlayer structure; and

15 d) a perpendicular magnetic recording layer disposed over said intermediate layer.

2. A magnetic recording medium as recited in Claim 1, wherein said substrate comprises aluminum coated with NiP.

20 3. A magnetic recording medium as recited in Claim 1, wherein said first soft underlayer has an average thickness of from about 50 nanometers to about 150 nanometers.

4. A magnetic recording medium as recited in Claim 1, wherein said second soft underlayer has an average thickness of from about 10 nanometers to about 40 nanometers.

25 5. A magnetic recording medium as recited in Claim 1, wherein said second soft underlayer has a thickness that is from about 10 percent to about 40 percent of the total thickness of said underlayer structure.

30 6. A magnetic recording medium as recited in Claim 1, wherein said underlayer structure has a total thickness of from about 50 nanometers to about 300 nanometers.

7. A magnetic recording medium as recited in Claim 1, wherein said first and second soft magnetic layers have a coercivity of not greater than about 10 Oe.

8. A magnetic recording medium as recited in Claim 1, wherein said first and second soft magnetic layers have a magnetic permeability of at least about 50.

5 9. A magnetic recording medium as recited in Claim 1, wherein said first and second soft magnetic underlayers are fabricated from the same magnetic material.

10. A magnetic recording medium as recited in Claim 1, wherein at least one of said first and second soft magnetic underlayers is fabricated from a material selected from the group consisting of CoZrNb, CoZrTa, FeCoB and FeTaC.

10 11. A magnetic recording medium as recited in Claim 1, wherein said spacer layer is fabricated from Ru.

12. A magnetic recording medium as recited in Claim 1, wherein said spacer layer has a thickness of from about 0.5 nanometers to about 5 nanometers.

15 13. A magnetic recording medium as recited in Claim 1, wherein said intermediate layer comprises a first intermediate sub-layer and a second intermediate sub-layer.

20 14. A magnetic recording medium as recited in Claim 1, wherein said intermediate layer comprises a first intermediate sub-layer selected from the group consisting of Ta, Ti or alloys thereof and a second intermediate sub-layer selected from the group consisting of Ru and alloys thereof.

15 15. A magnetic recording medium as recited in Claim 1, wherein said intermediate layer comprises a first intermediate sub-layer having a thickness of from about 1 nanometers to about 3 nanometers and a second intermediate sub-layer having a thickness of from about 5 nanometers to about 40 nanometers.

25 16. A magnetic recording medium as recited in Claim 1, wherein said perpendicular recording layer comprises an oxide selected from the group consisting of oxides of CoCrPt, CoCrPtB, CoCrPtSi and CoCrPtBSi.

30 17. A magnetic recording medium as recited in Claim 1, further comprising an exchange enhancement layer disposed between said non-magnetic spacer layer and said second soft magnetic underlayer.

18. A magnetic recording medium as recited in Claim 17, wherein said exchange enhancement layer is selected from the group consisting of Co, CoCr and CoFe.

19. A magnetic recording medium as recited in Claim 17, wherein said
5 exchange enhancement layer has a thickness of from about 1 to about 10 nanometers.

20. A magnetic recording medium for perpendicular recording, comprising:
a) a substrate;
b) an underlayer structure disposed over said substrate, said underlayer structure comprising:

- 5 i) a first soft magnetic underlayer having a first thickness;
 ii) a second soft magnetic underlayer and a third soft magnetic underlayer disposed over said first soft underlayer;
 iii) a first non-magnetic spacer layer disposed between said first and second soft magnetic underlayers; and
10 iv) a second non-magnetic spacer layer disposed between said second soft magnetic underlayer and said third soft magnetic underlayer, wherein said second and said third soft magnetic underlayers are anti-parallel coupled through said second non-magnetic spacer layer;
 c) an intermediate layer disposed over said underlayer structure; and
15 d) a perpendicular magnetic recording layer disposed over said intermediate layer.

21. A magnetic recording medium as recited in Claim 20, wherein said substrate comprises aluminum coated with NiP.

22. A magnetic recording medium as recited in Claim 20, wherein said first
20 soft magnetic underlayer has an average thickness of from about 50 nanometers to about 150 nanometers.

23. A magnetic recording medium as recited in Claim 20, wherein the total thickness of said second soft magnetic underlayer, said third soft magnetic underlayer and said second non-magnetic spacer layer is from about 20 nanometers to about 80
25 nanometers.

24. A magnetic recording medium as recited in Claim 20, wherein said second soft magnetic underlayer and said third soft magnetic underlayer have substantially the same thickness.

25. A magnetic recording medium as recited in Claim 20, wherein said first,
30 second and third soft magnetic layers have a coercivity of not greater than about 10 Oe.

26. A magnetic recording medium as recited in Claim 20, wherein said first, second and third soft magnetic layers have a magnetic permeability of at least about 50.

27. A magnetic recording medium as recited in Claim 20, wherein said first, second and third soft magnetic underlayers are fabricated from the same magnetic material.

28. A magnetic recording medium as recited in Claim 20, wherein at least one of said first, second and third soft magnetic underlayers is fabricated from a material selected from the group consisting of CoZrNb, CoZrTa, FeCoB and FeTaC.

29. A magnetic recording medium as recited in Claim 20, wherein said first non-magnetic spacer layer is selected from the group consisting of carbon, Ta or Ta-oxide.

30. A magnetic recording medium as recited in Claim 20, wherein said second non-magnetic spacer layer is fabricated from Ru.

31. A magnetic recording medium as recited in Claim 20, wherein said intermediate layer comprises a first intermediate sub-layer and a second intermediate sub-layer.

32. A magnetic recording medium as recited in Claim 20, wherein said intermediate layer comprises a first intermediate sub-layer selected from the group consisting of Ta, Ti or alloys thereof and a second intermediate sub-layer selected from the group consisting of Ru and alloys thereof.

33. A magnetic recording medium as recited in Claim 20, wherein said intermediate layer comprises a first intermediate sub-layer having a thickness of from about 1 nanometers to about 3 nanometers and a second intermediate sub-layer having a thickness of from about 5 nanometers to about 40 nanometers.

34. A magnetic recording medium as recited in Claim 20, wherein said perpendicular recording layer comprises an oxide selected from the group consisting of oxides of CoCrPt, CoCrPtB, CoCrPtSi and CoCrPtBSi.

35. A magnetic recording medium for perpendicular recording, comprising:
a) a substrate;
b) an underlayer structure disposed over said substrate, said underlayer structure comprising:

5 i) a first soft magnetic underlayer having a first saturation magnetization;

ii) a second soft magnetic underlayer having a second saturation magnetization, wherein said second saturation magnetization greater than said first saturation magnetization; and

10 iii) a spacer layer disposed between said first and second soft magnetic underlayers;

c) an intermediate layer disposed over said underlayer structure; and

d) a perpendicular magnetic recording layer disposed over said intermediate layer.

15 36. A magnetic recording medium as recited in Claim 35, wherein said substrate comprises aluminum coated with NiP.

37. A magnetic recording medium as recited in Claim 35, wherein said first soft underlayer and said second soft magnetic underlayer have substantially the same thickness.

20 38. A magnetic recording medium as recited in Claim 35, wherein said first soft underlayer is fabricated from a material selected from the group consisting of CoZrTa and CoZrNb.

39. A magnetic recording medium as recited in Claim 35, wherein said second soft underlayer is fabricated from a material selected from the group consisting of
25 FeCoB and CoFe.

40. A magnetic recording medium as recited in Claim 35, wherein said second saturation magnetization is at least about 100 emu/cm^2 higher than said first saturation magnetization.

41. A magnetic recording medium as recited in Claim 35, wherein said second
30 saturation magnetization is at least about 400 emu/cm^2 higher than said first saturation magnetization.